

UNITED STATES PATENT APPLICATION FOR:


**PAD ASSEMBLY FOR ELECTROCHEMICAL  
MECHANICAL PROCESSING**

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## **PAD ASSEMBLY FOR ELECTROCHEMICAL MECHANICAL PROCESSING**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application is a continuation-in-part of co-pending United States Patent Application Serial No. 10/642,128, filed August 15, 2003 (hereinafter the '128 application). The '128 application is a continuation-in-part of co-pending United States Patent Application Serial No. 10/608,513, filed June 26, 2003 (hereinafter the '513 application), which is a continuation-in-part of co-pending United States Patent Application No. 10/140,010, filed May 7, 2002. The '513 application is also a continuation-in-part of co-pending United States Patent Application No. 10/211,626, filed August 2, 2002, which is a continuation-in-part of co-pending United States Patent Application No. 10/033,732, filed December 27, 2001, which is a continuation-in-part of United States Patent Application No. 09/505,899, filed February 17, 2000. The '513 application is additionally a continuation-in-part of co-pending United States Patent Application Serial No. 10/210,972, filed August 2, 2002, which is also a continuation-in-part of United States Patent Application No. 09/505,899, filed February 17, 2000. The '513 application is further continuation-in-part of co-pending United States Patent Application No. 10/151,538, filed May 16, 2002. The '128 application is also a continuation-in-part of co-pending United States Patent Application Serial No. 10/244,697, filed September 16, 2002, which is a continuation-in-part of United States Application Serial No. 10/244,688, filed September 16, 2002, and of co-pending United States Patent Application Serial No. 10/391,324, filed March 18, 2003. All of the above referenced applications are hereby incorporated by reference in their entirety.

[0002] This application is additionally related to United States Patent Application Serial No. 10/033,732, filed on December 27, 2001; United States Patent Application Serial No. 10/455,941, filed June 6, 2003; and United States Patent Application Serial No. 10,455,895, filed June 6, 2003, all of which are also incorporated herein by reference in their entirety.

## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

[0003] Embodiments of the invention generally relate to a processing pad assembly for electrochemical mechanical processing.

### **Description of the Related Art**

[0004] Electrochemical Mechanical Processing (ECMP) is a technique used to remove conductive materials from a substrate surface by electrochemical dissolution while concurrently polishing the substrate with reduced mechanical abrasion as compared to conventional Chemical Mechanical Polishing (CMP) processes. With revising the polarity of the bias, ECMP systems may generally be adapted for deposition of conductive material on the substrate. Electrochemical dissolution is performed by applying a bias between a cathode and a substrate surface to remove conductive materials from the substrate surface into a surrounding electrolyte. The bias may be applied to the substrate surface by a conductive contact disposed on or through a polishing material upon which the substrate is processed. A mechanical component of the polishing process is performed by providing relative motion between the substrate and the polishing material that enhances the removal of the conductive material from the substrate.

[0005] Copper is one material that may be polished using electrochemical mechanical polishing. Typically, copper is polished utilizing a two-step process. In the first step, the bulk of the copper is removed, typically leaving some copper residue on the substrate's surface. The copper residue is then removed in a second step, typically referred to as an over-polishing step.

[0006] However, the removal of copper residue may result in dishing of copper features below the plane of a surrounding material, typically a dielectric or other barrier layer. The amount of dishing typically is related to polishing chemistries and processing parameters utilized in the over polish step, along with the width of the copper features subjected to polishing. As the copper layer does not have a uniform thickness across the substrate, it is difficult to remove all the

copper residue without causing dishing over some features and not removing all of the copper residue over others.

[0007] Thus, there is a need for an improved apparatus for electrochemical mechanical polishing.

#### **SUMMARY OF THE INVENTION**

[0008] In one embodiment, a processing pad assembly for processing a substrate is provided. The processing pad assembly includes an upper layer having a processing surface and an electrode having a top side coupled to the upper layer and a bottom side opposite the top side. A first set of holes is formed through the upper layer for exposing the electrode to the processing surface. At least one aperture is formed through the upper layer and the electrode.

[0009] In another embodiment, the processing pad assembly includes an upper layer having a processing surface and an electrode having a top side coupled to the upper layer and a bottom side opposite the top side. The electrode includes a first conductive zone and at least a second conductive zone. A first set of holes is formed through the upper layer for exposing the electrode to the processing surface. At least one aperture is formed through the upper layer and the electrode.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0010] So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

[0011] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0012] Figure 1 is a side view, partially in cross-section, of a processing station of an electrochemical mechanical processing system having a processing pad assembly;

[0013] Figure 2 is a partial sectional, exploded view of one embodiment of a platen and processing pad assembly of the processing station of Figure 1;

[0014] Figure 3 is a plan view of one embodiment of an electrode of a processing pad assembly of the processing station of Figure 1;

[0015] Figure 4 is a plan view of another embodiment of an electrode of a processing pad assembly of the processing station of Figure 1;

[0016] Figure 5 is a plan view of another embodiment of an electrode of a processing pad assembly of the processing station of Figure 1; and

[0017] Figure 6 is a plan view of another embodiment of an electrode of a processing pad assembly of the processing station of Figure 1; and

[0018] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

#### DETAILED DESCRIPTION

[0019] A processing pad assembly adapted to enhance uniform removal of material from a substrate is provided herein. The processing pad assembly includes at least an electrode and a processing pad. The processing pad may be non-conductive or conductive.

[0020] Figure 1 depicts a sectional view of a processing station 100 having one embodiment of a processing pad assembly 106 of the present invention. The processing station 100 includes a carrier head assembly 118 adapted to hold a substrate 120 against a platen assembly 142. Relative motion is provided therebetween to polish the substrate 120. The relative motion may be rotational, lateral, or some combination thereof and may be provided by either or both of the carrier head assembly 118 and the platen assembly 142.

[0021] In one embodiment, the carrier head assembly 118 is adapted to hold a substrate 120 against a platen assembly 142 disposed in an ECMP station 132. The carrier head assembly 118 is supported by an arm 164 coupled to a base

130 and which extends over the ECMP station 132. The ECMP station may be coupled to or disposed proximate the base 130.

[0022] The carrier head assembly 118 generally includes a drive system 102 coupled to a carrier head 122. The drive system 102 generally provides at least rotational motion to the carrier head 122. The carrier head 122 additionally may be actuated toward the ECMP station 132 such that the substrate 120 retained in the carrier head 122 may be disposed against a processing surface 104 of the ECMP station 132 during processing.

[0023] In one embodiment, the carrier head 122 may be a TITAN HEAD™ or TITAN PROFILER™ wafer carrier manufactured by Applied Materials, Inc., of Santa Clara, California. Generally, the carrier head 122 comprises a housing 124 and retaining ring 126 that define a center recess in which the substrate 120 is retained. The retaining ring 126 circumscribes the substrate 120 disposed within the carrier head 122 to prevent the substrate from slipping out from under the carrier head 122 during processing. It is contemplated that other carrier heads may be utilized.

[0024] The ECMP station 132 generally includes a platen assembly 142 rotationally disposed on a base 158. A bearing 154 is disposed between the platen assembly 142 and the base 158 to facilitate rotation of the platen assembly 142 relative to the base 158. The platen assembly 142 is typically coupled to a motor 160 that provides the rotational motion to the platen assembly 142.

[0025] The platen assembly 142 has an upper plate 114 and a lower plate 148. The upper plate 114 may be fabricated from a rigid material, such as a metal or rigid plastic, and in one embodiment, is fabricated from or coated with a dielectric material, such as chlorinated polyvinyl chloride (CPVC). The upper plate 114 may have a circular, rectangular or other geometric form with a planar upper surface. A top surface 116 of the upper plate 114 supports the processing pad assembly 106 thereon. The processing pad assembly 106 may be held to the upper plate 114 of the platen assembly 142 by magnetic attraction, static attraction, vacuum, adhesives, or the like.

[0026] The lower plate 148 is generally fabricated from a rigid material, such as aluminum and may be coupled to the upper plate 114 by any conventional means, such as a plurality of fasteners (not shown). Generally, a plurality of locating pins 146 (one is shown in Figure 1) are disposed between the upper and lower plates 114, 148 to ensure alignment therebetween. The upper plate 114 and the lower plate 148 may optionally be fabricated from a single, unitary member.

[0027] A plenum 138 is defined in the platen assembly 142 and may be partially formed in at least one of the upper or lower plates 114, 148. In the embodiment depicted in Figure 1, the plenum 138 is defined in a recess 144 partially formed in the lower surface of the upper plate 114. At least one hole 108 is formed in the upper plate 114 to allow electrolyte, provided to the plenum 138 from an electrolyte source 170, to flow through the platen assembly 142 and into contact with the substrate 120 during processing. The plenum 138 is partially bounded by a cover 150 coupled to the upper plate 114 enclosing the recess 144. Alternatively, the electrolyte may be dispensed from a pipe (not shown) onto the top surface of the processing pad assembly 106.

[0028] At least one contact assembly 134 is disposed on the platen assembly 142 along with the processing pad assembly 106. The at least one contact assembly 134 extends at least to or beyond the upper surface of the processing pad assembly 106 and is adapted to electrically couple the substrate 120 to a power source 166. The processing pad assembly 106 is coupled to a different terminal of the power source 166 so that an electrical potential may be established between the substrate 120 and processing pad assembly 106.

[0029] In other words, during processing, when the substrate 120 is held against the processing pad assembly 106, the contact assembly 134 biases the substrate 120 by electrically coupling the substrate 120 to one terminal of the power source 166. The processing pad assembly 106 is coupled to another terminal of the power source 166. The electrolyte, which is introduced from the electrolyte source 170 and is disposed on the processing pad assembly 106, completes an electrical circuit between the substrate 120 and the processing pad assembly 106, which assists in the removal of material from the surface of the substrate 120.

[0030] Figure 2 depicts a partial sectional, exploded view of the processing pad assembly 106 and platen assembly 142 of Figure 1. The processing pad assembly 106 includes at least a non-conductive upper layer 212 and a conductive lower layer, or electrode, 210. In the embodiment depicted in Figure 2, an optional subpad 211 is disposed between the electrode 210 and upper layer 212. The optional subpad 211 may be used in any of the embodiments of the processing pad assembly discussed herein. The electrode 210, subpad 211, and upper layer 212 of the processing pad assembly 106 may be combined into a unitary assembly by the use of adhesives, bonding, compression molding, or the like. In one embodiment, adhesive is used to attach the electrode 210, subpad 211, and upper layer 212 together. The adhesive may have a strong physical and/or chemical bond to the electrode 210, subpad 211, and upper layer 212 and may be resistant to electrolyte chemistries. Examples of suitable adhesive include, but are not limited to, urethane adhesives, acrylic adhesives, methacrylic adhesives, rubber-based adhesives, silicone adhesives, epoxy adhesives, and the like.

[0031] The adhesive bonding between the electrode 210, subpad 211, and upper layer 212 may be increased by the surface morphology of the materials selected to form the processing pad assembly 106 (*i.e.*, fabrics, screens, and perforations versus solids), or by the use of an adhesion promoter. The adhesion promoter may be conductive. Examples of adhesion promoters include, but are not limited to, silane coupling agents, titanate coupling agents, and the like. Alternatively, one or more of the surfaces being adhered may be chemically treated or plasma treated to increase adhesion. It is contemplated that any combination of surface morphology, coupling agents, or chemical or plasma treatments may be used to obtain the desired adhesion between layers of the processing pad assembly 106.

[0032] The upper layer 212 may be fabricated from polymeric materials compatible with process chemistry, examples of which include polyurethane, polycarbonate, fluoropolymers, PTFE, PTFA, polyphenylene sulfide (PPS), or combinations thereof, and other materials suitable for use in electrochemical processing environments. In one embodiment, a processing surface 214 of the



upper layer 212 of the processing pad assembly 106 is dielectric, for example, polyurethane or other polymer.

[0033] In another embodiment, the upper layer 212 of the processing pad assembly 106 may include a processing surface 214 that is conductive or made from a conductive composite (i.e., the conductive elements are dispersed integrally with or comprise the material comprising the processing surface), such as a polymer matrix having conductive particles dispersed therein or a conductive coated fabric, among others.

[0034] Examples of processing pad assemblies that may be adapted to benefit from the invention are described in United States Patent Application Serial No. 10/455,941, filed June 6, 2003 by Y. Hu et al. (entitled "CONDUCTIVE POLISHING ARTICLE FOR ELECTROCHEMICAL MECHANICAL POLISHING", attorney docket number 4500P4) and United States Patent Application Serial No. 10/455,895, filed June 6, 2003 by Y. Hu et al. (entitled "CONDUCTIVE POLISHING ARTICLE FOR ELECTROCHEMICAL MECHANICAL POLISHING", attorney docket number 4500P5), both of which are hereby incorporated by reference in their entireties.

[0035] In one embodiment, at least one permeable passage 218 is disposed at least through the upper layer 212 and extends at least to the electrode 210 – i.e., the permeable passage 218 is disposed in any intervening layers such as, for example, the subpad 211. The passage 218 allows an electrolyte to establish a conductive path between the substrate 120 and the electrode 210. The passage 218 may be a permeable portion of the upper layer 212, holes formed in the upper layer 212, or a combination of the two. The subpad 211, when present, may also be formed of a permeable material or include holes which align with the holes formed in the upper layer 212. In the embodiment depicted in Figure 2, the permeable passage 218 is a plurality of holes 216 formed in and through the upper layer 212 and the optional subpad 211 to allow an electrolyte to flow therethrough and come into contact with the electrode 210 during processing.

[0036] Optionally, an extension 222 of the permeable passage 218 may be formed in and at least partially through the electrode 210 (shown in phantom) in order to increase the surface area of the electrode 210 in contact with the

electrolyte. The extension 222 may extend completely through the electrode 210. Larger surface area of electrolyte contact with the electrode 210 improves the rate of removal of material from the surface of the substrate 120 during processing.

[0037] The subpad 211 is typically made of a material softer, or more compliant, than the material of the upper layer 212. The difference in hardness or durometer between the upper layer 212 and the subpad 211 may be chosen to produce a desired polishing (or deposition) performance. Generally, the subpad 211 may have a durometer in the range of from about 8 Shore O to about 20 Shore D. The subpad 211 may also be compressive. Examples of suitable subpad 211 materials include, but are not limited to, foamed polymer, elastomers, felt, impregnated felt and plastics compatible with the processing chemistries.

[0038] The electrode 210 is disposed on the top surface 116 of the upper plate 114 of the platen assembly 142 and may be held there by magnetic attraction, static attraction, vacuum, adhesives, or the like. In one embodiment, adhesive is used to adhere the electrode 210 to the upper plate 114. It is contemplated that other layers, such as release films, liners, and other adhesive layers, may be disposed between the electrode 210 and the upper plate 114 to facilitate ease of handling, insertion, and removal of the processing pad assembly 106 in the processing station 100.

[0039] The electrode 210 has at least one terminal 202 to facilitate coupling to the power source 166, for example by securing the terminal 202 to a lead 204 of the power source 166 with a stainless steel screw (not shown). The electrode 210 may act as a single electrode, or may comprise multiple independent electrode zones isolated from each other. The electrode 210 is typically comprised of a corrosion resistant conductive material, such as metals, conductive alloys, metal coated fabrics, conductive polymers, conductive pads, and the like. Conductive metals include Sn, Ni, Cu, Au, and the like. Conductive metals also include a corrosion resistant metal such as Sn, Ni, or Au coated over an active metal such as Cu, Zn, Al, and the like. Conductive alloys include inorganic alloys and metal alloys such as bronze, brass, stainless steel, or palladium-tin alloys, among others. Metal coated fabric may be woven

or non-woven with any corrosion resistant metal coating. Conductive pads consist of conductive fillers disposed in a polymer matrix. The electrode 210 should also be fabricated of a material compatible with electrolyte chemistries to minimize cross-talk between zones when multi-zoned electrodes are utilized. For example, metals stable in the electrolyte chemistries are able to minimize zone cross-talk.

[0040] When metal is used as material for the electrode 210, it may be a solid sheet. Alternatively, the electrode 210 may be formed of a metal screen (as shown by electrode 510 depicted in Figure 5) or perforated (as shown by electrode 610 as depicted in Figure 6) in order to increase the adhesion to the upper layer 212 or optional subpad 211. The electrode 210 may also be primed with an adhesion promoter, as discussed above, to increase the adhesion to the upper layer 212 or optional subpad 211. An electrode 210 which is perforated or formed of a metal screen also has a greater surface area, which further increases the substrate removal rate during processing.

[0041] When the electrode 210 is fabricated from metal screen, a perforated metal sheet, or conductive fabric, one side of the electrode 210 may be laminated, coated, or molded with a polymer layer which penetrates the openings in the electrode 210 to further increase adhesion to the upper layer 212 or optional subpad 211. When the electrode 210 is formed from a conductive pad, the polymer matrix of the conductive pad may have a high affinity or interaction to an adhesive applied to the upper layer 212 or optional subpad 211.

[0042] At least one aperture 220 is formed in the electrode 210, optional subpad 211, and upper layer 212 of the processing pad assembly 106. Each of the at least one apertures 220 is of a size and location to accommodate a contact assembly 134 disposed therethrough. In one embodiment, the at least one aperture 220 is a single aperture formed in the center of the processing pad assembly 106 to accommodate a single contact assembly 134.

[0043] The contact assembly 134 is coupled to the power source 166. Although only one contact assembly 134 is shown coupled to the upper layer 114 of the platen assembly 142 in Figure 2, any number of contact assemblies

134 may be utilized and may be distributed in any number of configurations on the upper layer 114 of the platen assembly 142.

[0044] Figures 3 and 4 show bottom views of alternative embodiments of electrodes having multiple zones that may be advantageously adapted for use with the various embodiments of the invention described herein. In Figure 3, the electrode 310 includes at least one dielectric spacer and at least two conductive elements. The conductive elements are arranged to create a plurality of independently biasable zones across the surface of the electrode 310. In the embodiment depicted in Figure 3, the electrode 310 has at three conductive elements 350, 352, 354 that are electrically isolated from each other by dielectric spacers 390 to create electrode zones, an outer electrode zone 324, an intermediate electrode zone 326, and an inner electrode zone 328. Each electrode zone 324, 326, 328 – shown separated by a dashed boundary 380 – may be independently biased to allow the substrate polishing profile to be tailored. One example of a polishing method having electrode zone bias control is described in United States Patent Application Serial No. 10/244,697, filed September 16, 2002, which is hereby incorporated by reference in its entirety.

[0045] Although the electrode zones 324, 326, 328 and conductive elements 350, 352, 354 are shown as concentric rings, the electrode zones may be alternatively configured to suit a particular polishing application. For example, the electrode zones 324, 326, 328 and/or conductive elements 350, 352, 354 may be linear, curved, concentric, involute curves or other shapes and orientations are possible for the conductive elements. The electrode zones 324, 326, 328 and/or conductive elements 350, 352, 354 may be of substantially equal sizes and shapes from one zone to the next, or the sizes and shapes may vary depending upon the particular zone of concern.

[0046] Figure 4 depicts another embodiment of an electrode 410 having a plurality of independently biasable electrode zones. In one embodiment, the electrode 410 has at least  $n$  zone electrodes (shown as three electrodes 410<sub>1</sub>, 410<sub>2</sub>, and 410<sub>3</sub>), wherein  $n$  is an integer of 2 or greater. The electrodes 410<sub>1</sub>, 410<sub>2</sub>, and 410<sub>3</sub> each include a respective terminal 402<sub>1</sub>, 402<sub>2</sub>, 402<sub>3</sub> for coupling to a power source. The electrodes 410<sub>1</sub>, 410<sub>2</sub>, and 410<sub>3</sub> are generally separated by a dielectric spacer 406 or an air gap and each form an

independent electrode zone. The electrodes 410<sub>1</sub>, 410<sub>2</sub>, and 410<sub>3</sub> may include one or more apertures 420 to facilitate interfacing with one or more conductive elements, such as the contact assemblies 134 depicted in Figures 1 and 2.

[0047] While the foregoing is directed to the illustrative embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.